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SOME PROPERTIES OF FREEZE-DRIED PORK MUSCLES OF HIGH OR LOW ULTIMATE pH

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Introduction

In a previous paper[1] it was shown that some of the deleterious effects of the Accelerated Freeze Drying process (AFD)[2] on beef steaks could be lessened by using muscle with a high ultimate pH. Beef of high ultimate pH injected preslaughter with adrenaline, was found to be more tender, more juicy and less ' woody ' after freeze-drying than control beef with a normal ultimate pH. Since pork muscle is also likely to be used in the commercial preparation of AFD products, it seemed desirable to ascertain the effect of a high ultimate pH in the muscles of the pig.

Experimental

Injection and sample preparation

Two litter-mate pigs of the Large White breed were employed. One of these was given a subcutaneous injection of adrenaline (500 μg./kg.) 24 h. before slaughter and another dose (250 μg./kg.) $2\frac{1}{2}$ h. before slaughter. The other pig, which was not injected, served as a control. *Longissimus dorsi* (lumbar), *psoas*, *biceps femoris* and *semimembranosus* muscles were dissected from both sides of each carcass.

The muscles were sealed in polythene pouches and frozen at $-20°$. Slices 12 mm. thick were cut from each muscle, some being held at $-20°$ to serve as frozen reference samples and the remainder freeze-dried in an AFD pilot plant. The control and treated samples from each muscle were dried simultaneously so that each was subjected to the same drying conditions. No difference was found in the drying times of the control and treated muscles. The dried slices were gas-packed under nitrogen in cans and held at room temperature until required.

Cooking and tasting

Dehydrated whole steaks were reconstituted by immersion in tap water and holding under vacuum for 20 min. In one series the steaks were casseroled in the reconstitution water for $1\frac{1}{2}$ h. in an oven at 185° ; and in the other they were fried in fat, 5–7 min. each side. The taste panel (6 members) was asked to assess the tenderness, juiciness and flavour as follows:

0 : very tough, very dry and very weak pork flavour
6 : tender, juicy and normal pork flavour

In addition each taster was asked to give a personal opinion as to the acceptability of the meat on a hedonic scale where 1 represented ' dislike extremely ', and 9 represented ' like extremely '.

Tenderometer measurements

The tenderness of frozen and rehydrated pork cooked by steaming for $1\frac{1}{4}$ h. was measured on a tenderometer, by the method previously described.[1]

Reconstitution

Reconstitution was determined on cylinders of the dehydrated pork, cut with a cork borer, using the centrifuging method described by Aitken *et al.*[3] During reconstitution and centrifuging, solids were leached out by the water. The weights of these were determined by evaporating the liquid to dryness. Results were expressed as g. water/g. dry weight (the dry weight having been corrected for the losses due to leaching).

Measurement of fibre diameter

The diameter of fibres, teased from the frozen slices after thawing and from rehydrated slices, was measured by the method described in the earlier paper.[1]

Results

Ultimate pH

The effectiveness of adrenaline in raising the ultimate pH of the muscles can be seen from Table I, the pH increment being greatest in the *psoas* and least in the *longissimus dorsi* muscles.

Tasting

The tenderising effect of a high ultimate pH which was found in beef was also found in pork as shown by the taste panel results in Table II.

Table I

Ultimate pH of fresh muscles from adrenaline-treated and control pigs

Muscle	Treated		Control	
	Right	Left	Right	Left
Longissimus dorsi	6·42	6·59	5·49	5·40
Psoas	7·20	7·10	5·55	5·28
Biceps femoris	6·94	7·17	5·53	5·50
Semimembranosus	6·88	6·61	5·42	5·39

The treated muscles were more tender than the controls. Dehydration again made the meat tougher but the improvement obtained with the high ultimate pH remained in the dried steaks.

It is interesting to note in the results for the fried steaks that, although the treated meat was more tender and juicy than the control, it was considered less acceptable to the panel. This would appear to be due to the loss of flavour in the treated samples. A loss of flavour in the casseroled samples was also reported but in this case the treated samples were generally more acceptable, although the increase in acceptability was not as great as one would have anticipated from the difference in tenderness.

In addition to the loss of flavour, some of the fried treated frozen steaks had a peculiar texture, which could be described as ' rubbery ' even though the meat was very tender. This texture was not observed in the dehydrated treated steaks, nor to the same degree in the casseroled samples.

Table II

Effect of freeze-drying on the eating quality of pork muscles of high or low ultimate pH. Taste panel results
(average scores of 6 tasters)

(A) Casseroled pork muscles

	Longissimus dorsi		*Biceps femoris*		*Semimembranosus*	
	Frozen	Freeze-dried	Frozen	Freeze-dried	Frozen	Freeze-dried
Tenderness						
Treated	4·4	3·8	6·0	5·2	5·4	4·9
Control	3·8	2·8	2·6	2·4	1·8	1·2
Juiciness						
Treated	3·4	2·2	4·4	5·0	3·8	3·4
Control	1·8	3·2	3·2	3·6	2·4	2·4
Flavour						
Treated	4·0	3·2	3·6	4·0	2·8	4·0
Control	3·8	4·6	4·5	4·5	3·4	4·0
Acceptability						
Treated	5·2	4·2	5·8	6·0	4·6	5·4
Control	4·0	4·4	4·8	5·8	3·4	3·4

(B) Fried pork muscles

	Longissimus dorsi		*Psoas*		*Biceps femoris*		*Semimembranosus*	
	Frozen	Freeze-dried	Frozen	Freeze-dried	Frozen	Freeze-dried	Frozen	Freeze-dried
Tenderness								
Treated	5·2	3·8	5·2	5·8	5·2	4·3	4·6	4·4
Control	4·0	3·2	4·2	3·2	2·4	2·0	2·8	1·8
Juiciness								
Treated	4·6	3·2	4·2	3·8	5·0	3·2	4·6	3·6
Control	4·4	4·0	4·8	2·1	3·2	2·0	4·2	2·8
Flavour								
Treated	3·6	3·4	3·0	3·0	3·6	2·8	3·8	3·0
Control	4·2	4·4	5·2	4·5	3·6	4·0	4·8	4·2
Acceptability								
Treated	5·8	4·8	6·2	5·8	5·0	4·0	5·4	4·0
Control	6·0	6·0	7·5	5·2	4·8	3·2	5·4	3·8

The panel was small and its opinions on acceptability may not be representative. However, it would appear that the majority of the members of the panel prefered a fried steak that had a good flavour, even if it was moderately tough, to a steak which was very tender but lacking in flavour.

Tenderometer measurements

The taste panel results for tenderness were confirmed by tenderometer measurements (Table III). (It should be noted that the ' tenderometer ' data, in fact, are directly proportional to toughness and inversely to tenderness.) The treated muscles before and after freeze drying were much more tender than the controls. The *semimembranosus*, as was found in beef, was the muscle which showed the greatest decrease in toughness. It is again clear that dehydration has the general effect of toughening the meat.

Table III

Measurement of work done (ergs × 10^6/cm.) by a tenderometer in shearing meat 1 cm. thick under a constant load of 15 kg.

	Treated	Treated dehydrated	Control	Control dehydrated
Longissimus dorsi	6·8	9·7	16·2	16·8
Psoas	8·0	10·1	16·2	17·7
Biceps femoris	8·8	8·8	15·7	16·5
Semimembranosus	8·0	11·2	21·0	24·8

Reconstitution

Although the centrifuging method of reconstitution does not measure true ' bound ' water, it provides an empirical method by which any difference in water binding between treated and control material can be revealed and measured. The results in Table IV show that the treated meat not only absorbed more water during rehydration and held more water after centrifuging, but retained a greater percentage of the water absorbed than the control. These facts illustrate the greatly enhanced water-binding capacity of the treated muscles.

Table IV

Weight of water/g. dry weight absorbed during rehydration of AFD pork muscles, and the weight and percentage of water retained after centrifuging at 2000 g for 45 min.

	After rehydration	After centrifuging	% retained after centrifuging
	g. H_2O/g. dry wt.		
Treated			
Biceps femoris	3·44 ± ·09	2·21 ± ·17	58·5
Semimembranosus	3·33 ± ·10	2·19 ± ·09	60·7
Longissimus dorsi	3·03 ± ·12	2·03 ± ·10	60·4
Control			
Biceps femoris	2·74 ± ·11	1·60 ± ·11	52·4
Semimembranosus	2·63 ± ·05	1·59 ± ·06	53·9
Longissimus dorsi	2·73 ± ·12	1·52 ± ·05	48·0

Measurement of fibre diameter

The mean diameters of the fibres of frozen and rehydrated unfixed materials are given in Table V. The differences between frozen control and treated samples were not consistent, since in two muscles the control had a larger mean fibre diameter than the treated muscle and in the other two the reverse was the case. Similarly in the rehydrated sample two of the treated muscles had a greater mean fibre diameter than the controls, and two were almost the same, the difference being well within the limits of experimental error.

The level of rehydration as indicated by the measurement of fibre diameter is shown in the last two columns of Table V. Rehydrated control samples had a mean fibre diameter equal to or less than that of frozen control samples. Rehydrated treated samples were more variable, however. Rehydrated *longissimus dorsi* and *biceps femoris* were slightly greater than their frozen counterparts, but *semimembranosus* considerably exceeded the value obtained for the

Mean fibre diameter of muscle with a high and low ultimate pH following freezing and rehydration

Muscle	Frozen		Rehydrated		% rehydration	
	Control	Treated	Control	Treated	Control	Treated
Semimembranosus	90·1 ± 20·4	73·8 ± 14·9	78·1 ± 12·4	95·5 ± 20·6	86	131
Psoas	60·6 ± 19·0	69·8 ± 13·3	61·2 ± 9·9	57·8 ± 14·9	101	83
Longissimus dorsi	89·3 ± 15·5	79·8 ± 18·9	78·1 ± 17·9	83·7 ± 16·4	87	105
Biceps femoris	82·8 ± 16·8	99·1 ± 23·7	83·8 ± 13·6	100·2 ± 16·9	101	103

frozen treated sample. The rehydrated sample of treated *psoas* had a mean fibre diameter which was about 20% less than that of the frozen sample of the same muscle.

In comparing the rehydrated controls with rehydrated treated samples it may be seen that, in each case except *psoas*, the mean diameters of fibres from treated muscles are greater than those from control muscles.

Effect of the pH of the reconstituting medium on the properties of AFD pork of low ultimate pH

Since the improvements in tenderness and water-holding capacity described above had been effected by high ultimate pH, the influence of the pH of the reconstituting medium on the properties of the AFD pork with a low ultimate pH was also considered.

The difficulty was that of finding an appropriate buffer. It was found that, in order to raise the pH of the control from 5·4 to 6·8, buffers like tris, sodium glycerophosphate or sodium bicarbonate had to be used at too high an ionic strength, or at too high a pH. Thus, if pieces of pork were reconstituted in these media, solubilisation of the proteins occurred before reconstitution was complete. On the other hand, buffers such as pyrophosphate *per se* increase the water-holding capacity of muscle by a specific action, and therefore would not give comparable results. An imidazole buffer, however, was found to be satisfactory for the purpose intended and the effect on reconstitution and tenderness was determined on the AFD control muscles of low ultimate pH.

To find the effect of environmental pH on reconstitution, cylinders of pork were cut and reconstituted in solutions of imidazole of various strengths. Two pieces were reconstituted in each solution, one being used to determine pH and the other being weighed and centrifuged as described previously. The results are shown in Table VI.

Increasing the pH of the rehydrating media has the effect of increasing both the amount of water absorbed during rehydration and the amount held after centrifuging. When the pH of the meat was raised to 6·8, the water absorbed and held reached the level of the treated meat of intrinsically high ultimate pH with the exception of the *biceps femoris*.

Table VI

Effect of environmental pH on reconstitution of AFD pork muscle

Muscle	Molarity of imidazole	pH of reconstituted muscle	Reconstitutability: After rehydration (g. H_2O/g. dry wt.)	Reconstitutability: After centrifuging (g. H_2O/g. dry wt.)	% retained after centrifuging
Longissimus dorsi	0	5·40	2·73	1·52	48
	0·05	6·00	3·06	1·74	52
	0·10	6·45	3·20	1·94	59
	0·125	6·82	3·02	2·05	58
Biceps femoris	0	5·35	2·74	1·60	54
	0·025	5·85	2·83	1·65	51
	0·05	6·40	2·95	1·74	52
	0·10	6·80	3·00	1·80	54
	0·125	7·00	3·13	1·87	53
Semimembranosus	0	5·35	2·63	1·59	54
	0·025	5·75	2·76	1·62	53
	0·05	6·12	2·92	1·93	59
	0·075	6·35	3·05	1·86	51
	0·10	6·62	3·17	2·08	54
	0·125	6·85	3·22	2·22	60

To examine the effect on tenderness, pieces of the dried muscle were rehydrated in 0·1M-imidazole, or in water, for 20 min. under vacuum. The pieces were then cooked for $1\frac{1}{4}$ h. and the toughness measured by a tenderometer as described previously.

Comparison of the results in Table VII with those in Table III shows that, although AFD meat was tenderised by reconstitution in imidazole, it did not reach the level of tenderness brought about by a high ultimate pH. Nevertheless, the *longissimus dorsi* and *biceps femoris* muscles were appreciably more tender : on the other hand, *semimembranosus*, which was a very tough muscle, remained tough after reconstitution in imidazole. This was the muscle which showed the largest decrease in toughness after adrenaline treatment.

Table VII

Tenderness of AFD pork muscle after rehydration in 0·1M-*imidazole or in water as measured by a tenderometer*
(ergs × 10^6/cm.)

	Reconstituted in water	Reconstituted in 0·1M-imidazole
Longissimus dorsi	17·0	12·3
Biceps femoris	16·0	11·5
Semimembranosus	24·6	22·5

Discussion

The results for pork muscle presented here confirm those previously obtained for beef. The benefits that accrue as a result of a high ultimate pH are increased tenderness and increased juiciness, improvements which are retained after the meat has been subjected to the AFD process. The only detrimental feature of the meat with a high ultimate pH is the loss of flavour. Whether this would affect the general acceptability of meat so treated is not known, but the taste panel preferred the tougher frozen control sample which had a better flavour when fried.

The improvement in the texture of the dehyrated pork after reconstitution is associated with an increase in the water absorbed. This was shown both by measurements of fibre diameter and by the water retained after centrifuging. The response to the adrenaline showed some variation between muscles. The ultimate pH in *longissimus dorsi* was less high after treatment than the others ; the diameter of the rehydrated *psoas* treated fibres was slightly less than the control (whereas all the other treated muscles had a greater fibre diameter) and the *semimembranosus* showed the greatest degree of tenderising. The amount of water held by the AFD treated *longissimus dorsi* muscle after reconstitution and centrifuging was less than the amount held by the other muscles. This muscle, especially when fried, also showed a relatively greater degree of toughening after drying, according to the taste panel data, than the other muscles. These two findings may be directly associated with the relatively lower ultimate pH of the treated *longissimus dorsi* muscle.

An improvement in the tenderness, and in the amount of water held during reconstitution, of freeze-dried meat can be obtained by rehydrating in a medium of high pH. The effect, however, does not appear to be the same as that produced by a high ultimate pH. All the muscles of a high ultimate pH absorbed more water and retained more water than the control muscles after rehydration and centrifugation. The *biceps femoris* muscle from the control pig, on the other hand, although it absorbed more water in the buffer at a high pH, did not retain the excess after centrifuging. Similarly, all the treated muscles were tender, but the *semimembranosus* of the control remained tough after reconstitution in imidazole buffer of high pH.

It is not known how the addition of imidazole would affect the eating quality, nor, of course, what possible harm ingestion of imidazole may do. It is doubtful, therefore, if this would be a suitable method for practical purposes.

The induction of a high ultimate pH, therefore, has the effect of improving the texture of both beef and pork after processing by Accelerated Freeze Drying. In practice there is no difficulty in attaining a high pH with adrenaline. Such meat however should not be treated for sale as a fresh commodity since its high pH could accelerate bacterial spoilage. In its AFD form, meat with a high ultimate pH should generally be found more attractive than normal AFD meat.

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